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AGARD REPORT No. 717

Some Trends in Airship Technology Developments

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Report No. 717

SOME TRENDS IN AIRSHIP TECHNOLOGY DEVELOPMENTS

by

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PREFACE

Increasing attention is being now paid to the possibility of using dirigibles more widely because of the flexibility of performance of the lighter-than-air (LTA) concept. Attention is being focused on the potential improvements offered by advances recently made in aerospace technology. For its part, the Structures and Materials Panel has an interest in the application of new materials and novel structures, and an activity to consider those aspects has been set up by the Panel at its Spring 1983 Meeting in London.

This pilot paper was presented at this Meeting. It demonstrates that significant reductions in structure weight can be achieved through the use of new materials, such as carbon fibre composites, and goes on to show what corresponding improvements in operational performance can be gained.

The data given here are encouraging; they provide a starting point for future developments.

P.SANTINI
Chairman, Sub-Committee on
Materials & Structures for Dirigibles

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SOME TRENDS IN AIRSHIP TECHNOLOGY DEVELOPMENTS

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AGARD 56th PANEL MEETING London 10-15th April 1983

SUMMARY

Some problem areas for the advance of modern airships are pointed out.

A typical long range sea patrol mission is considered.

In particular the use of composite materials for the structure and for the envelope, in order to achieve a substantial reduction of the empty weight and consequently a performance improvement, is considered.

INTRODUCTION

Recently several proposals for the lighter-than-air (LTA) aircraft use have been presented, which take into account technological advance in structural materials, propulsion systems and control techniques. It is claimed that such advances would permit the design of new airships which are both safer and more efficient.

Such kinds of design include light weight envelopes and structures, light weight engines and advanced controls and instrumentation.

Thus a modern airship would have better performances than historical airships of comparable volume.

However the obvious limits of the airship that make it non-competitive whith commercial air transport lead to deeper inspections for special missions of the airships. The most appealing application for a modern conventional airship could be a long range maritime patrol mission, because of the payload capacity and endurance.

The airships have higher speed than ships and greater endurance and higher payload capacity than airplanes [1].

1. – EMPTY WEIGHT EFFECT

In order to evaluate the airship efficiency the first item to be considered is the empty weight (¹) effect.

The ratio empty weight to volume (W_e/V) versus volume for several airships – Akron, Macon, Hindenburg included – is shown in Fig. 1.

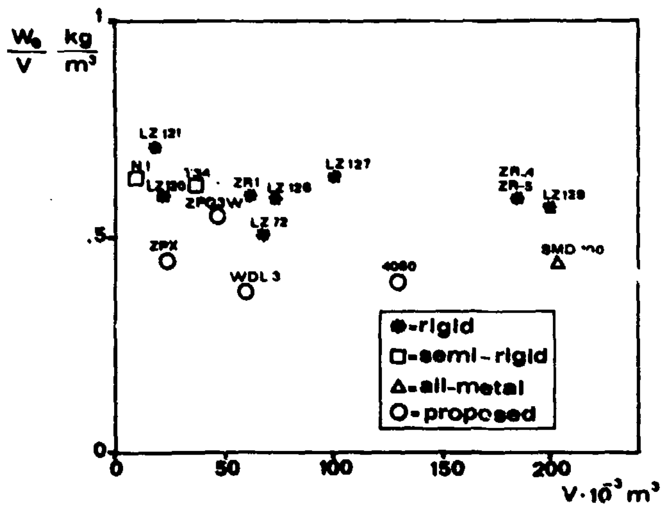


Fig. 1

(¹) The empty weight is given by the gross weight less lifting gas weight and useful and fuel weight.

One can see that, despite the replacement of steel with aluminum alloys in the rigid structure, this ratio is close to being practically constant as volume increases.

Therefore the efficiency does not increase with size, typical values of current technology are in the area $W_e/V = 0.55$ kg/m³. The contribution of the individual parts of the rigid airship to the above values are shown in Table 1.

TABLE 1 – Rigid Airships

COMPONENTS	W_e/V(kg/m³)
ENVELOPE AND GAS BAGS	.100*
RIGID STRUCTURE	.185
PROPULSION	.100
CAR, CONTROLS, INSTRUMENTATION, ...	.165

* for the semi-rigid and non-rigid airships the value changes to .2 and .3

Several proposed airships, which could use new lighter structural materials, are considered in Fig. 1 [4].

As one can see the ratio W_e/V is significantly reduced and a more advanced value $W_e/V = .35$ might be achieved with current technology.

Empty weight also affects cruise altitude. For $W_e/V = .5$ and $W_e/V = .3$, values of the ratio of useful load at various altitudes, W_u, and useful load at sea level, W_{u0}, versus altitude, are presented in Fig. 2, for helium practical lifting force of 1 kg/m³.

It appears that the empty weight effect on the altitude capability is very significant.

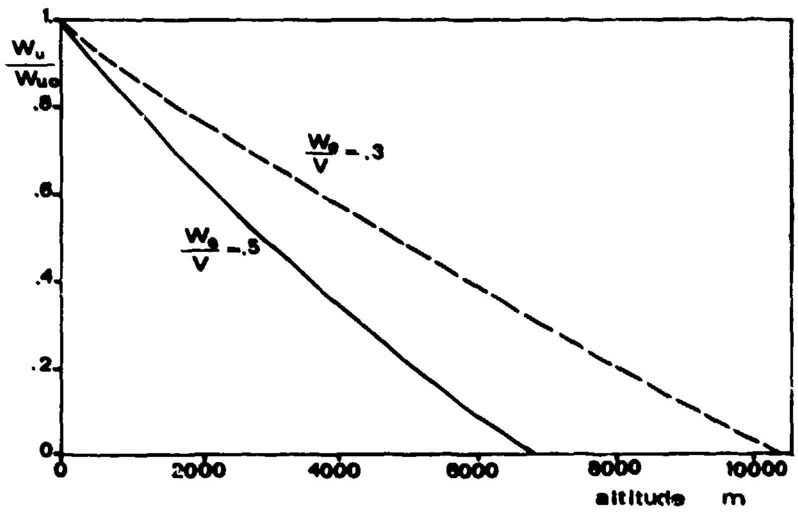


Fig. 2

2. – PERFORMANCE ANALYSES

In order to evaluate the potential effectiveness of modern airships with a reduced structural weight, some performances are presented by using the drag and propulsive efficiency of designs of the past.

Range increase, d, versus volume for two cruise velocities and several ratios, W_e/V, is shown in Figs. 3 and 4. In this analysis the ratio W_u/V is kept constant, so that the weight of the fuel, W_f, increases as the ratio W_e/V is improved. The productivity, (defined by payload tons • range kilometers) versus volume is presented in Fig. 5.

Conversely if the ratio W_f/V is kept constant (so that the payload increases as the ratio W_e/V is improved) one gets the values of productivity, as defined by payload tons • range kilometers/fuel kilos, which are shown in Fig. 6.

But it is important to add another significant parameter such cruise velocity; thus, by redefining the productivity as the ratio (payload range • cruise velocity/fuel required), we obtain the Fig. 7, for a 200,000 m³ airship and two ratios W_e/V.

From the above considerations it is possible to guess a possible configuration of the airship for a sea patrol mission.

For instance Fig. 8 shows for a mission, as defined by range, payload and cruise velocity, the values of volume computed as a function of the ratio W_e/V [5], [6].

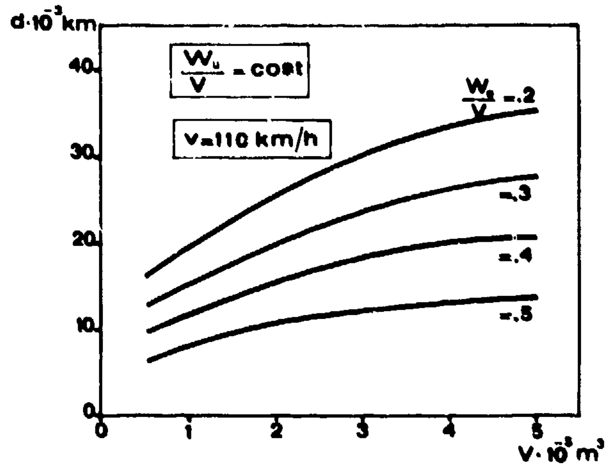
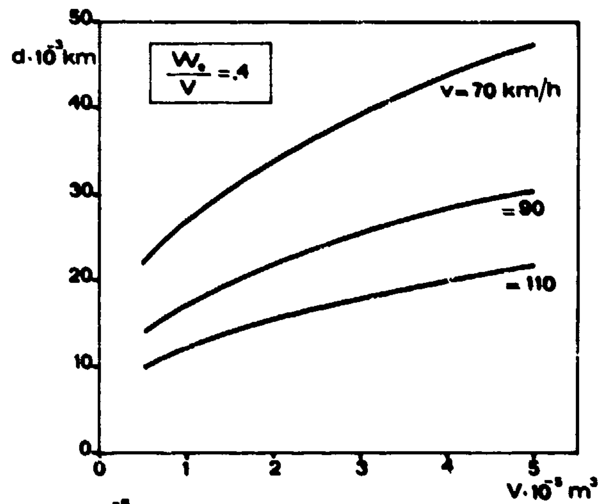


Fig. 3



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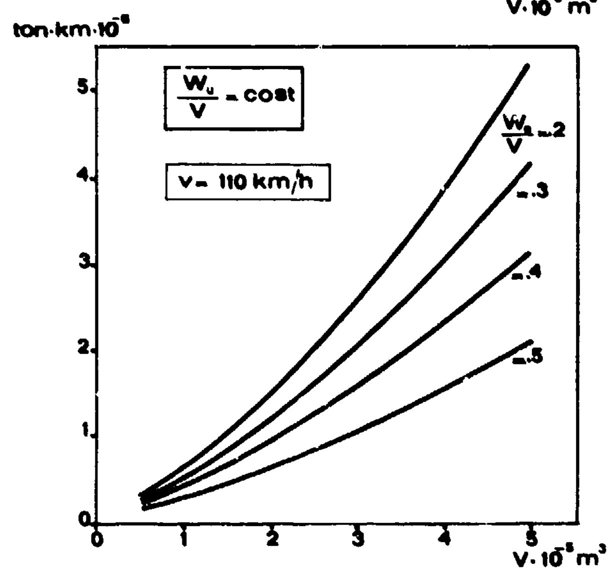

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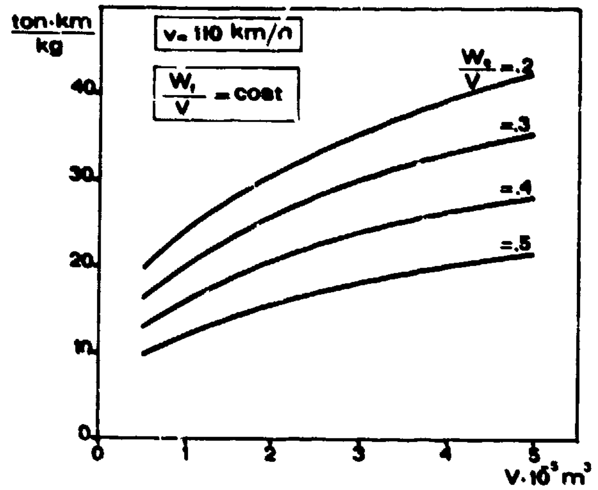

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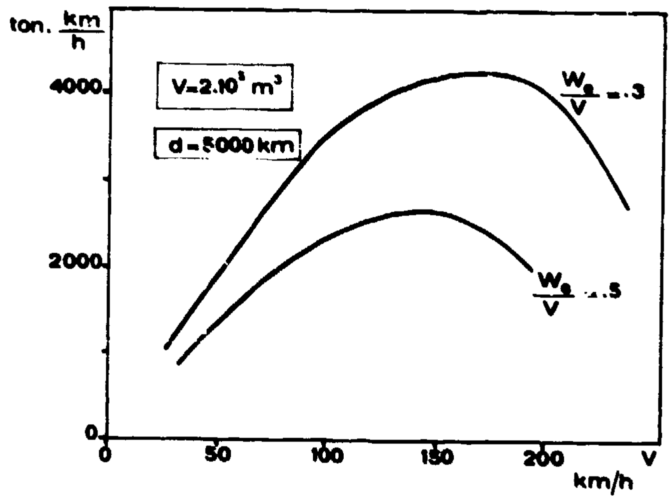

Fig. 7

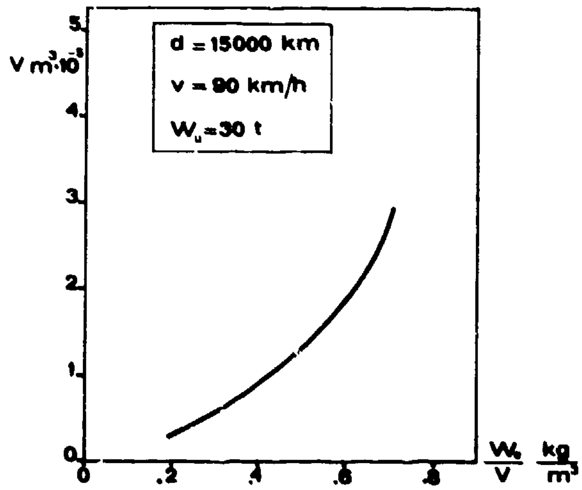

Fig. 8

3. – TECHNOLOGICAL ADVANCE IN MATERIALS

The previous analysis shows that one gets a significant improvement as the ratio W_e/V decreases.

This decrease may be achieved by new structural materials and new fabrics for the envelope [7], [8].

In the field of propulsion, improvements in aircraft engines may allow to save up to 75% of the relevant weight. In this area, emphasis should now be placed on the thrust vector control tecnique in order to get an autonomous capability in hovering, landing and take-off.

In the structural materials field one can see a definite trend towards the use of composite materials which have received large application in the aircraft and spacecraft construction.

As for the primary structure (e.g. girder and rigid frame) is concerned composite materials as carbon fiber and kevlar fiber (see Table 2 for properties) could be used.

TABLE 2 – Structural materials

STRUCTURAL MATERIALS	DENSITY $kg\ m^{-3}$	YOUNG' MODULUS GPa	TENSILE STRENGTH GPa
7075 Alluminum	2700.	75.	.41
Titanium	4500.	116.	1.10
Glass Fiber	2100.	50.	1.20
Carbon Fiber	1600.	200.	1.00
Kevlar fiber	1400.	85.	1.40

Weight saving, as compared to an analogous aluminum alloy structure, may be as high as 30 percent; that is in agreement with the prevision of the composite materials application for new design studies concerning primary structures, e.g. the wing, in aircraft structures [9].

A second significant saving can be achieved by using new fabrics for the envelope.

The propertie of these materials, which have a large use for the high altitude scientific ballons, are presented in Table 3.

TABLE 3 – Envelope Materials

MATERIALS	WEIGHT $gr\ m^{-2}$	TENSILE STRENGHT $kg\ m^{-1}$	PERMEABILITY $l\ m^{-2}$ (24 hr)
Rubber cotton	90.	800.	3.
Polyethylene	10.	250.	1.
Mylar	55.	500.	.30
Mylar Dracon	55.	800.	1.75
Nylon Nylon	65.	850.	2.

In comparison with the historical envelopes of cotton-reinforced rubber, the new materials use could save about 35 ÷ 40 percent.

At last, if also the secondary structural members (e.g. car, control surfaces, rigging, ...) are manufactured from composite materials, a further saving of 15 percent could be achieved. It is well known that kevlar fibers have been used in the airship AD-500 Skyship.

This approach offers, in the last analysis, reductions in overall weight which could lower the ratio W_e/V, for the future airships, to .35 (see Table 4), [10].

In this case, as one can see by Fig. 8, a significant reduction in the system size is achieved.

For example for a typical sea patrol long range mission, defined by a seven days endurance and a 30 tons payload, a reduction in the ratio W_e/V from .55 to .35 should permit the use of an airship of 70,000 m^3 class.

TABLE 4 – Advanced airships

COMPONENTS	W_e/V kg/m^3
ENVELOPE AND GAS BAGS	.06
RIGID STRUCTURE	.14
PROPULSION	.03
CAR, CONTROLS, INSTRUMENTATION, ...	.12

4. – PROBLEM AREAS

In the Authors' opinion it is possible to indicate the following major problem areas in order to get a significant improvement in the airship performances, based on the technology available in the 90's:

1 – primary structure construction in composite materials;
2 – secondary structure construction in composite materials;
3 – pliant material technology for envelopes and gas cells;
4 – modern computer techniques in analysis of airship structures;
5 – thrust vector control capability;
6 – airship dynamics and control at low velocities;
7 – airship operations, ground handling and ground facilities;
8 – development of new certification rules.

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14. Abstract

Recent advances in aerospace technology, and in particular the application of new materials and novel structures, have special relevance to the development of dirigibles. This paper demonstrates that significant reductions in structure weight can be achieved through the use of, for example, carbon fibre composites. It goes on to show what corresponding improvements in operational performance can be gained.

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